Experimental study of an original radiographic view for diagnosis of cam-type anterior femoroacetabular impingement

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Abstract

Purpose Primary paraclinical investigation to look for femoral morphological abnormality consistent with cam-type anterior femoroacetabular impingement (FAI) must include specific radiographic projections of the hip from the following: cross-table, frog-leg or Dunn (90° and 45° flexion). We use a frog-leg type view with fixed angles as described by Chiron, obtained with the patient in a supine position, with the hip in 45° flexion-abduction and 30° external rotation. The X-ray beam is anteroposterior and centred on the femoral head. We evaluated this view by comparing it with other views in common use.

Methods In this experimental study, we created artificial radio-opaque morphological abnormalities secured onto normal femoral necks. The femurs were placed in relation to a fixed pelvis using orthogonal landmarks, in the positions of the various radiographic views. The digital radiographs were analysed by two observers. Nineteen femurs were included to reveal a difference of 5° between the alpha angle of Nötzli et al. [11] measured on the Dunn view and the frog-leg 45/45/30 view (Student's paired test).

Results The highest mean values of the alpha angle of Nötzli were always obtained with the frog-leg 45/45/30 view (87.4°, 86.2°, 84.5°) and the lowest with the cross-table view. We found a mean difference of 8.95° with the 90° Dunn view ($P=0.00007$), 3.44° with the 45° Dunn view ($P=0.004$) and 13.47° with the cross-table view ($P=0.002$).

Conclusions This experimental study confirmed the value of the frog-leg 45/45/30 view in assisting diagnosis of cam-type FAI.

Introduction

Anterior femoroacetabular impingement (FAI) is caused by abutment between the bone of the anterior and proximal aspect of the femoral neck and the acetabular rim [1, 2]. The diagnosis is based above all on clinical symptoms (pain on flexion-internal rotation of the hip) and observation of a morphological abnormality on imaging [3].

In cam-type FAI, the morphological abnormality lies at the anterosuperior part of the head-neck junction [4, 5].

During the 2008 AOA symposium [6] on hip disease in the young adult, it was stated that the primary paraclinical investigation to seek bone abnormalities consistent with FAI should include an anteroposterior hip radiograph and one of the following specific lateral views [7]: cross-table, frog-leg or Dunn view (90° [8] and 45° flexion [9]). The anteroposterior view reveals pincer-type abnormality in FAI [10], while the lateral hip view detects cam-type abnormality.

Measurement of the alpha angle of Nötzli et al. [11] on a Dunn view is a reliable and sensitive means of quantifying the morphological abnormality causing a cam effect [12].

In our department, since 2005, we have used the modified frog-leg view described by Chiron and Laffosse [13] for

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the diagnosis and follow-up of our patients with FAI. This image is obtained with the patient supine, with the hip in 45° flexion-abduction and 30° external rotation. The X-ray beam is anteroposterior and centred on the femoral head (Fig. 1). We called this view the frog-leg 45/45/30 view.

The purpose of our study was to evaluate this view by comparing it with other views used to look for the morphological abnormality found in FAI. We assessed the reproducibility and the validity of the frog-leg 45/45/30 view.

Materials and methods

Simulation of a radio-visible artificial femoral morphological abnormality

Twenty human bone specimens (one pelvis and 19 femurs) were supplied by the anatomy laboratory of our institution. Morphological abnormalities of the head-neck junction were simulated by hemi-elliptical metal inserts of identical size placed in bone incisions in healthy femoral necks at locations described in the literature [3–5] at 30° on the anterior superior aspect at the head-neck junction (Fig. 2). We identified the top of the femoral neck, i.e. the most cranial point at the base of the neck and at the head-neck junction, and using a protractor we measured an anterior angle of 30° and then marked the two points on the bone. The bone was incised in the axis of the straight line thus obtained, that is, radially to the axis of the neck.

Fig. 1 Position of the patient for the frog-leg 45/45/30 view, seen posteriorly

Fig. 2 Semi-ellipse simulating the apex of a femoral abnormality at 30° on the anterior aspect at the head-neck junction

When the insert had been placed, all the radiographs were obtained without changing its position. The abnormality was fixed and identical for each femur.

Standardisation of radiographic views

The pelvis was positioned on a hard surface in accordance with the quality criteria for an anteroposterior pelvic radiograph [7]. The assembly was rigid and fixed. We identified the transverse axis passing through the centre of the two acetabuli and placed protractors on each side. We did the same with the sagittal axis of abduction-adduction. The axes were indicated by latex strings. When the chosen angles were marked on the protractors, we placed the femoral head in the acetabulum and the centre of the lower part

Fig. 3 Accurate, reproducible views obtained with a fixed pelvis and protractors: right frog-leg 45/45/30 view

of the femur at the intersection of the two lines to obtain the desired view (Fig. 3).

When the two extremities of the string attached to the protractors measuring flexion were at an equal distance from the centre of the protractor, the axis shown by the string was parallel to the transverse axis. Rotation was measured as the angle between the epicondylar axis and the transverse axis.

Views studied

The Dunn view [8] is made with the patient in a supine position, 90° flexion, 20° abduction and neutral rotation. The radiograph is centred on the hip with an anteroposterior X-ray beam. The 45° Dunn view [9] is made with the patient in a supine position, in 45° flexion, 20° abduction and neutral rotation. The radiograph is centred on the hip with an anteroposterior X-ray beam. The cross-table view is made with the patient in a supine position; the contralateral hip and knee are flexed and the symptomatic limb is in 15° internal rotation. The X-ray beam is parallel to the table, centred on the femoral head and oriented 45° medially to the hip being studied. The frog-leg 45/45/30 view [13] is made in 45° flexion, 45° abduction and 30° external rotation. The radiograph is centred on the hip with an anteroposterior X-ray beam. Source-to-hip and hip-to-film distances were constant for all measurements. Tension and intensity values were fixed (81 KV, 20mAs).

Radiological analysis

All radiographs were scanned into JPEG format and analysed using OsiriX software (Fig. 4) [14]. After calibration by measurement of the pubic symphysis (3.5 cm), we determined the following: the femoral head centre, by positioning a best-fit circle; and the axis of the femoral

neck, by drawing a line passing through the centres of the medial and lateral sides of the quadrilateral representing the neck. The alpha angle was measured as described by Nötzli et al. [11]. Each measurement was made by two observers (EC, NR). EC carried out two measurements at an interval of three weeks.

Statistical analysis

The sample size (number of femurs) required to meet the principal objective was calculated to observe a minimum difference of 5° between the Nötzli angle measured on the Dunn view and the frog-leg 45/45/30 view (Student's paired test). Assuming that the standard deviation of the Nötzli angle will be 10° on both views (following Meyer et al. [9]) and that the angle measured on our view will be correlated with the angle measured on the Dunn view with a correlation coefficient of 0.7 or higher, the number of subjects required was 19 for an alpha risk of 5 % and a power of 80 %.

The measurements on the different views were compared using the Student's *t*-test or the Wilcoxon matched test, depending on normality of the data.

To calculate the required sample size, we assessed the validity of alpha angle measurement on the frog-leg 45/45/30 view. It is necessary to ensure that measurement of the alpha angle on this view and on the Dunn view varies in the same proportions for different morphological abnormalities. Validity is assessed by comparing the alpha angle values obtained between the two views by Spearman's correlation coefficient.

Intra and inter-observer reproducibility rates were measured by intraclass correlation coefficients between two measurements made by the first observer (intraobserver reproducibility) and between two measurements made by the two observers (interobserver reproducibility).

Fig. 4 Dataset obtained with Osirix software

First-order risk was 5 %. Analysis was carried out using Stata SE v11.0 software (StataCorp, College Station, TX, USA).

Results

Descriptive analysis

The highest mean values of the alpha angle of Nötzli were always obtained with the frog-leg 45/45/30 view (87.4°, 86.2°, 84.5°) (Fig. 5). The lowest values were obtained with the cross-table view.

Comparison

All comparisons of the four views revealed a higher alpha angle value on the frog-leg 45/45/30 view (difference of 8.95° compared with the 90° Dunn view, 3.44° with the 45° Dunn view and 13.47° with the cross-table view), differences that were statistically significant ($P=0.00007$, $P=0.003$ and $P=0.002$, respectively) (Table 1).

Reproducibility

Intra- and inter-observer reproducibility ranged from 0.87 to 0.93 for alpha angle measurement for all views studied (Table 2). The inter-observer ICC for the frog-leg 45/45/30 view was 0.93 and the intra-observer ICC was 0.91.

Validity

The Spearman correlation coefficient was $r=0.7$ between the alpha angle values measured on the Dunn view and the frog-leg 45/45/30 view.

Discussion

The simulated morphological abnormality was identical for each femur, the radiographs were obtained in a standardised manner and radiographic parameters were constant. The only variable was the radiographic view.

We positioned the artificial abnormalities at the locations described in the literature. As it is difficult to recreate a 3D model, we chose to simulate only the top of the abnormality, which is the part best described in the literature. Several authors agree that there is a peak increase in the alpha angle at 30° in the anterosuperior quadrant. Ito et al. [5], in an MRI study, observed that maximum reduction of head–neck offset lay around the one o'clock position at the head–neck junction, defining the twelve o'clock position as the most cranial part of a sagittal section of a femoral neck. Beaulé et al. [4] analysed cartilage and labral lesions around the one o'clock position in cam-type FAI. Hack et al. [3] sought to assess the prevalence of femoral morphological abnormalities in an asymptomatic population. In an MRI study, they found that 14 % of hips had a cam-type deformity. The most elevated alpha angles were observed at the 1:30 position.

Fig. 5 Alpha angle (mean and standard deviation) according to view and to observer (EC, NR)

Table 1 Comparison of alpha angle values measured using the frog-leg 45/45/30 view and the other views by the two observers (standard deviation)

Difference between frog-leg 45/45/30 and other views	Observer 1 (EC)		Observer 2 (NR)
	Measurement 1	Measurement 2	
90° Dunn	8.95 (2.3) $P=0.00007$	6.98 (2.12) $P=0.0006$	7.75 (2.47) $P=0.01$
45° Dunn	3.44 (0.94) $P=0.003$	3.18 (0.81) $P=0.002$	1.79 (1.09) $P=0.14$
Cross-table	13.47 (3.26) $P=0.002$	13.17 (2.32) $P=0.0002$	11.29 (2.77) $P=0.002$

Tannast et al. [15] also mapped labral lesions by comparing peroperative findings and CT data obtained using computer simulation. They found the majority of lesions in the cam group at the one o'clock position.

Calculation of the required sample size was based on comparison with the Dunn view, which several authors consider as the view of choice [12]. This calculation requires sufficient correlation between the alpha angle values for the two views. This is what we termed the measurement of validity by calculation of Spearman's correlation coefficient, in this case 0.7 which corresponds to our initial objective. We considered a minimum difference of 5° to be significant. The aim of our study was reached with a mean difference of 8.95° ($P=0.00007$) between the frog-leg 45/45/30 view and the Dunn view.

With regard to alpha angle measurement, the highest values were found with the frog-leg 45/45/30 view. For an equivalent morphological abnormality, the frog-leg 45/45/30 view gave a higher alpha angle value. It is a good screening investigation.

Intra- and inter-observer reproducibility for measurement of the alpha angle was excellent (intra-observer ICC 0.91, inter-observer ICC 0.93) with the frog-leg 45/45/30 view. This calculation may be biased by the experimental nature of the study, as the point at which the head ceases to be spherical is more easily identified than in vivo.

The view studied is a variation of the frog-leg view. There are no precise descriptions of the angles of the frog-leg view [16], and they may vary, for hip flexion in particular is

dependent on the suppleness of the patient or on the volume and distribution of their fat mass, among other factors. This hampers the reproducibility of this view. Angle values are thus an advantage for obtaining more accurate and repeatable measurements.

Meyer et al. [9], in an experimental study on dry bone, compared six different radiographic views. They classified their femur sample in two groups, those with a spherical head and those with a non-spherical head. The six views compared were the 90° Dunn view, the 45° Dunn view, an anteroposterior view and a cross-table view in internal, neutral and external rotation. They obtained the highest absolute values of the alpha angle on the 45° Dunn view.

Clohisy et al. [16], in a retrospective study, compared the alpha angle on three radiographic views in an impingement group and a control group. The three views were a frog-leg, an anteroposterior and a cross-table view. They analysed the difference obtained for each view between the impingement group and the control group. The greatest difference was obtained with the frog-leg view. We also compared our view with the cross-table view, and our results for the alpha angle were greater, for similar abnormalities (difference 13.47°, $P=0.002$).

Konan et al. [17] compared the alpha angle values obtained on plain radiographs and on CT scans. In the same subject, the alpha angle values were higher on CT scan. The CT scans were axial 3D reconstructions of the femoral neck. These authors concluded that plain radiography is an inexpensive and readily available screening tool.

Barton et al. [12] studied the diagnostic possibilities of alpha angle measurement on the Dunn view and found a sensitivity of 91 % and a specificity of 88 %.

The frog-leg 45/45/30 view is routinely used in our department. Chiron et al. [18] assessed 118 cases of cam-type FAI. The morphological abnormality was visualised with this view and was confirmed by CT and MRI scans, and the correction could also be measured pre- and postoperatively with the same view. As early as the first visit, it is of great assistance in determining whether the patient has a morphological abnormality consistent with FAI; radiographic discovery of a femoral neck abnormality must of course be interpreted in conjunction with clinical assessment. The

Table 2 Intra and inter-observer reproducibility of alpha angle measurement (95 % confidence interval)

View	Intra-class correlation coefficient	
	Intra-observer	Inter-observer
Frog-leg 45/45/30	0.91 (0.83–0.99)	0.93 (0.89–0.97)
Cross-table	0.92 (0.85–0.99)	0.87 (0.8–0.91)
90° Dunn	0.9 (0.82–0.99)	0.92 (0.85–0.99)
45° Dunn	0.87 (0.76–0.98)	0.93 (0.88–0.99)

view is obtained with the patient in a supine position, with the hip in 45° flexion and abduction. By placing the ipsilateral foot against the contralateral knee, 30° external rotation is obtained.

Conclusions

This experimental study, whose only variable was the radiographic view, confirmed the value of the view in 45° flexion, 45° abduction and 30° external rotation, the frog-leg 45/45/30 view, in assisting diagnosis of cam-type anterior femoroacetabular impingement. It is a good screening test for femoral head abnormalities compatible with FAI.

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